

# Build Contesting Scores by Killing Receive Noise

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As a west coast contester, I'm not competitive in DX contests, so I often operate QRP in pursuit of the personal challenge of 5BDXCC with 5W. I've been very pleasantly surprised how much I can work when the station on the other end can hear well. The problem is that many stations with big transmitted signals have poor receive capability. When we can't hear well, it's easy to turn into a CQ machine, and miss a lot of QSOs. This article is about tracking down and killing the noise that is killing our RX and costing us QSOs! We'll begin by talking about the three basic kinds of noise, then how to identify them by type, how to track them down, and how to suppress the noise they generate.

**How Much Noise is Normal?** The noise we hear when the band is open is propagated like any other signal from a distant QTH. A good rule of thumb is that for a reasonably quiet QTH, noise on the HF bands should increase by at least 10 dB when the band opens. A QTH inside most cities and suburbs may be a lot noisier, but increasing the observed difference at your QTH will help you hear more of the weaker stations on the band. And even in a quiet QTH, the noise should drop to the level of its own circuit noise when we disconnect our antenna from the radio. If this doesn't happen, either the antenna is performing poorly on that band or the radio needs a preamp.

To evaluate noise levels, and the effectiveness of our attempts at noise reduction, we need some reasonably accurate and reproducible method of measuring it. That can be the S-meter in our radio, or a spectrum display or analyzer, but whatever we use, it must provide readings that are consistent from one setup to the next on the same band.

**Most S-Meters Are Inaccurate** – they may be calibrated at S9, but the difference between S-units typically varies from 5 dB near S9 to 3 dB at S6 and below, and the "dB over S9" may be equally inaccurate. Calibration of the meter in the Elecraft K3 and K3S is much better than average, and can be user-calibrated from the "tech" menu with a calibrated signal source. Calibration also carries over to the P3 spectrum display.

Noise on our ham bands is of three basic types. The one we're most familiar with is *impulse noise*, most often generated by defective equipment in the *mains power system* and by *lightning*. In the power system, impulse noise is generated by something arcing, typically a defective insulator, transformer, or a broken conductor that's intermittent. *Defective neon signs* are another source of impulse noise. WX5L notes that *forced air attic ventilators thermostats* can create impulse noise as they age especially if they are near the fan as it vibrates the surrounding area.

The ordinary "static" we hear from the AM broadcast band up to about 40M is impulse noise – lightning from millions of sources, propagated like any other radio wave, from discharges near and far. The loudest crashes are nearby; the more distant lightning blends together to form a more uniform din. Impulse noise is quite broadband, and consists of the infinite harmonics of the impulse.

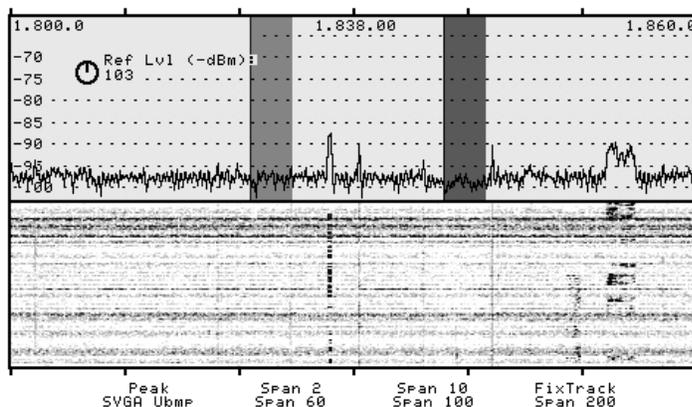


Fig 1 – Static Crashes On 160M

The strength of impulse noise tends to fall off both with increasing frequency and in increasing distance from the source. The strength of power line noise (and even whether it is present at all) also varies with weather, especially humidity.

In Fig 1, the horizontal lines in the waterfall are static crashes, the vertical ones are signals. The one around 1828 kHz is a CW signal, the weak ones around 1831 and 1839 kHz are probably electronic noise, and there's an LSB signal around 1854 kHz.

**Electronically Generated Noise** is the second basic type, and in recent years have become the dominant sources for most of us. Electronic noise sources include anything with a microprocessor, any digital electronics, variable-speed motor controllers, DC-AC inverters, charge controllers in solar power systems, and switch-mode power supplies (SMPS). SMPS are used as the low voltage

power supply (mostly in the range of 5 – 24VDC) for cable TV decoders, the electronics in home entertainment systems, laptops, phones, and low voltage lighting. These power supplies often come in the form of wall warts and cord lumps that power all sorts of electronics, and that charge batteries for everything from mobility scooters and power tools to cell phones. They may also be built into the electronics themselves – TV sets, computers, refrigerators – virtually anything that plugs into the 120VAC line. The charge controllers and DC to AC inverters that are part of solar power systems can generate high noise levels if poorly designed and/or poorly installed. We'll discuss solar power systems later on.

The average home in the developed world typically has at least thirty such potential noise sources (and often more), and we hear not only our own but those in our neighbors' homes. The noise produced by these sources is mostly radiated by cables attached to the sources, although in larger appliances like refrigerators and the variable speed motors in a furnace, wiring internal to the source may radiate the trash. It's simple antenna action – by virtue of poor design, the noise source leaks common mode current onto external cables and differential current onto internal wiring, both of which become antennas.

**Signal Leakage** from equipment or wiring is a third type of interference. Fig 2 shows leakage from a VDSL modem from about 3.7 – 5 MHz that strongly affects the 75M band. With help from W0QE, W0IVJ captured this spectral plot from an SDR in his Toyota as he drove around his neighborhood. The broad hump of noise is from the modem – the spikes are from an SMPS in his Toyota, as well as from other noise sources in the neighborhood. The spike at 5 MHz is WWV's carrier. This RFI will be heard as noise or hash. Tom recorded this as a video, which he has posted at <https://www.youtube.com/watch?v=HIGMmEgzhv0&feature=youtu.be>. There's more about this form of RFI later in this document where we address issues and solutions with specific product types.

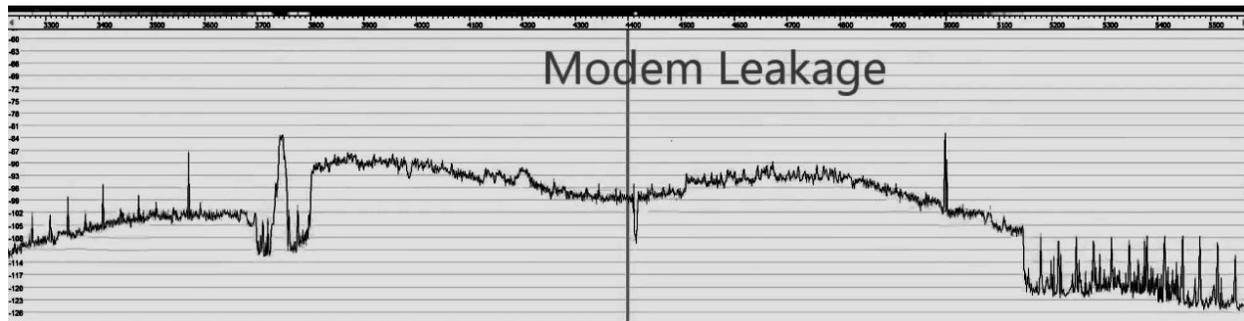


Fig 2 –VDSL/Cable Modem 3.2MHz – 5.6 MHz, 3dB/div

### Optimize Your Station First

There are some things we can do with our stations, and that *we should do before chasing noise sources*. We can 1) *use antenna directivity* to point away from noise and toward the stations we want to work; 2) *locate antennas* as far as practical from noise sources – height helps with this, and generally makes them better DX antennas; 3) use an effective *ferrite common mode choke at the feedpoint of every antenna*; 4) *horizontal antennas* are usually (but not always) quieter than vertical antennas; 5) avoid off-center-fed antennas (which are inherently noisy) and open-wire-fed antennas, neither of which can be effectively choked, and (6) implement *proper bonding and grounding* within your station and throughout your home. [I'll be writing about grounding and bonding in the future; in the meantime, see <http://k9yc.com/GroundingAndAudio.pdf> and W9RE's "Station Tending" column from Sept/Oct 2015 NCJ.]

**Use A Common Mode Choke At The Feedpoint of Every Receive (and Transmit) Antenna** to prevents the antenna feedline from becoming part of the antenna. This reduces receive noise because 1) our antennas are usually up in the air and more distant from noise sources, so they receive less noise by virtue of their distance from sources in our own home and those of our neighbors; and 2) antennas reject some noise by virtue of their directivity. An effective choke on the feedline at the feedpoint also prevents signals picked up on the feedline from entering the cable as differential mode signals, and from filling in the nulls of the antenna's directional pattern. For general and spe-

cific guidelines for feedline chokes see <http://k9yc.com/RFI-Ham.pdf> and the companion Power Point slides <http://k9yc.com/CoaxChokesPPT.pdf>

## Locating Noise Sources

**Common Mode and Differential Mode Transmission:** Most RF noise is transmitted as a *Common Mode* signal on wiring connected to the source – that is, the wiring radiates because noise current is flowing on a coax shield, or in the same direction on all conductors. It's simple antenna action. *Differential Mode* transmission is a voltage *between* the wires that make up the path, with current on the pair flowing in opposition. Very little RFI is the result of differential mode transmission, so filters are rarely of any use. If a filter is used, it must be carefully designed so that it does not degrade transmission of the desired signal.

**Power Line Noise Current** (and the current from arcing neon signs) flows on wires connected to the arcing source, and is radiated by those conductors by simple antenna action. Low frequency components of the noise use very long lengths of those conductors, while higher frequency components use the parts of the conductors that are very close to the source. Those low frequency components can travel pretty long distances – it's not at all uncommon for hams in rural areas to hear arcing power lines 10-20 miles away on the lower ham bands.

It's quite difficult to locate the source of power line noise at low frequencies, both because the wires radiating those components are so long, and also because the noise may travel along the lines as a differential signal, creating peaks and nulls in voltage and current (power lines are transmission lines at RF as well as at power frequencies). The key to locating the source of power line noise and other impulse noise is to search for it at VHF and UHF. I own several tools that work well for this. If the source is within walking distance, a handheld AM RX that can tune to VHF and/or UHF is a big help. I have two – a Kenwood TH-F6A talkie, and a Tecsun PL660. The Tecsun PL660 and PL880 receive AM on the MF and LF AM bands, and from just above the 160M band to nearly 30 MHz. The PL660 also receives AM on the 118-137 MHz aviation band, while the PL880 does not. The PL880 got a positive review from ARRL Labs a few years back. The Tecsun radios use DSP technology, and happen to be excellent AM and FM receivers for both SWL and entertainment. The TH-F6A can receive AM from just above the audio spectrum to 1.3 GHz (although it's not very sensitive below VHF), and maintains maximum sensitivity to about 550 MHz. If the source is beyond easy walking distance, a VHF/UHF FM mobile rig that also tunes AM is a great tool. My current favorite is a Kenwood TM-V71A.

The two Kenwood rigs have many memories that can be programmed either manually or from an accessory computer program. In addition to repeater frequencies, I've programmed my TH-F6A and TM-V71A for AM on 160, 200, 300, 400 MHz, and that highest frequency of maximum sensitivity around 550 MHz. When searching for the source of power line noise, I drive around tuned to 160 MHz looking for the signal; when I find it, I switch to higher frequencies as it gets stronger. When I'm hearing it peak at 550 MHz, I get out of the car with the talkie tuned to that frequency.

Foxhunts held by my Chicago area ham club taught me that placing a talkie with a rubber duck close to my chest would block signals from behind me, making it a simple directional antenna. This makes it possible to locate the source by direction, then move toward it. We could get even more directivity by attaching a small 440 MHz Yagi and setting the radio for AM around 440 MHz.

Ideally, we want to identify the source location as precisely as possible before calling the power company. By all means, get an address, intersection, or lat/long coordinates, even the identifying numbers on a pole nearby. (Record ALL of the numbers on the pole – every service on the pole will assign it a different ID. The power company will know which one is theirs.) The closer we can get the power company's investigating team to the source, the more likely it is to be found and fixed (and the more your expertise will be respected). ARRL can provide advice on contacting the power company, and what to do if things don't go as well as you hope. Power companies generally respond fairly well to find the source, because it often points to a potentially dangerous condition or a likely point of failure. But here in California, those same power companies have a poor record of fixing problems that only cause noise; Garry, NI6T, has learned that it's because administrators of the teams that fix things are rewarded if they have spent less of their budget at the end of a year.

At least one local ham, an attorney, has had good results contacting the state agency that regulates his local power company when this has occurred.



Fig 3 – Some RFI Hunting Tools

ARRL has great resources for understanding and dealing with Power-Line Noise. Start with this well written and comprehensive webpage. <http://www.arrl.org/power-line-noise>

**Electronic Noise Sources:** Just as with power line noise, our first task is to identify the noise as electronically generated, zero in on the source, and once we've found it, apply suppression to kill it. Electronic noise sources, (except for those sources that generate arcing), are some form of square wave. Square waves produced by **Switch-Mode Power Supplies** (SMPS) are usually in the range of 10-30 kHz, and they are not stable in frequency. They are free-running oscillators, and, to get around FCC Rules for radiated noise at a single frequency, are frequency-modulated by random noise. This produces the characteristic carriers spaced 20-60 kHz apart (2X the frequency of the square wave), each carrier surrounded by sidebands of noise, that drift up and down the band as they warm up, or as their load condition changes. When we hear (or see on our rig's spectrum display) these drifting carriers surrounded by humps of noise, we know that the culprit is some form of switching power supply or DC to AC inverter. If the carriers don't move, the source is most likely circuitry linked to the clock for a microprocessor or other digital electronics.

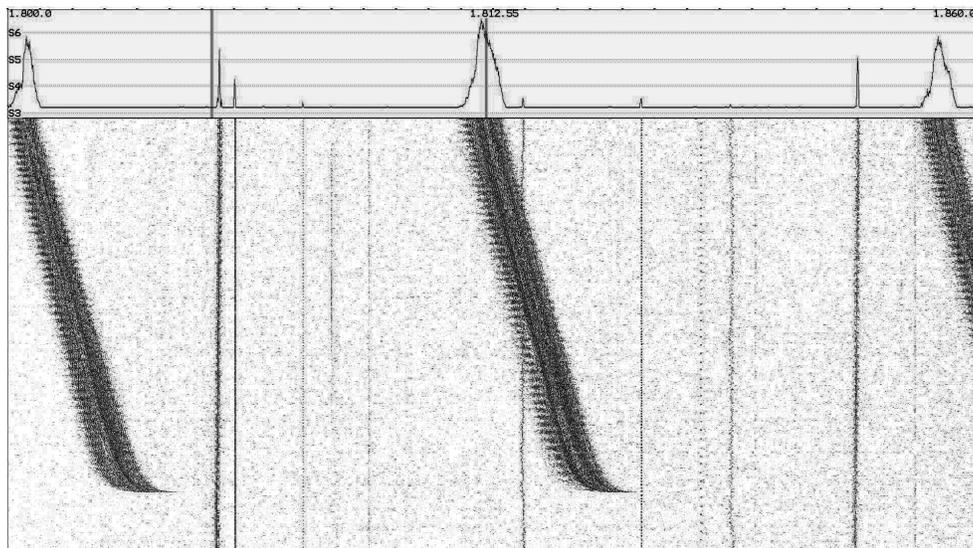


Fig 4 – Spectrum of a Switch Mode Power Supply

Fig 4 shows the classic spectral signature of a Switch-Mode power supply (SMPS), as well as eleven signals that are likely generated by a stable clock for digital electronics. This screen shot shows the lower 60 kHz of the 160M band; the total height (duration) of the waterfall displays about 165 seconds. The noise source is an SMPS in my shack that was turned on (about 30 seconds above the bottom of the waterfall). The repetition rate of this SMPS is about 14 kHz, half the spacing between frequency peaks. The straight vertical lines in the waterfall are electronic noise produced by digital equipment, probably from several different sources. At least one, the weak signal just to the right of the pulsed signal around 1840 kHz, is drifting down in frequency at a much slower rate, so it is also an SMPS. An SMPS sounds like a gurgly carrier surrounded by noise. If it's weak, we'll hear only the carrier.

Electronically generated noise is generally not broadband, but rather is stronger in some frequency ranges than others. The 33V power supplies that SteppIR supplied for their controllers when long cable runs would be used generated extremely strong RFI on the higher HF bands, especially on 12M. Even with heroic efforts I was unable to choke it effectively, and I eventually replaced it with a home brew linear supply.

Wired Ethernet cables radiate what sounds like White noise at VHF, and individual carriers in the HF and low VHF spectrum. Those carriers are stable in frequency and synchronized to the Ethernet switch, but the tolerance on frequency is wide enough that you'll typically hear your own and your neighbors' at slightly different frequencies centered around 14,030 kHz, 21,052 kHz, the low ends of 10M and 6M, and a few frequencies on 30M. These are only some of the carriers, but I'm a CW guy, so they're the ones I've identified. I don't know of any Ethernet noise components below 30M.

When chasing electronic noise, it's always best to start at home. In doing so, we lower our noise level so that we can hear our neighbors' noise, and we also learn to identify the sources and suppress them. A good start is to first kill power to your home while listening to your rig while it's running on batteries. Most rigs draw only 1-2A on receive, so a 12V battery of relatively modest capacity is sufficient for short listening periods. There are a couple of bear traps though; first, we need power for accessories like antenna switching that keep our rig connected to the desired antenna(s). This can be tricky in some stations. Second, we must make sure that a UPS doesn't keep noisy equipment going when we think it's turned off. For most of us, that means unplugging and putting to sleep laptops and tablets, and temporarily shutting down other computers. The noise that remains with our own home shut down is outside our home. [For this series of tests, it's best to listen on antennas close to the house; if your primary antennas are more distant, try rigging a random wire near the house for this test.]

The next step is to turn power back on, one circuit at a time, and carefully listen to all bands and all antennas for any noise that wasn't there with the power off. Each time a new source appears, identify and record what's connected to the circuit that just turned on, make notes of what's connected to it, and then using our portable radio as a signal probe to see if we hear noise. Alternatively, turn off each piece of equipment on that circuit and listen for the noise to disappear. As you identify each source, suppress it, before moving on to the next one.

This process goes a lot faster and works a lot better with another ham who either flips breakers and turns equipment on and off or listens in the shack as you do the power switching, using VHF radios to communicate. While doing this, consider that most SMPS drift as they warm up, so will have shifted in frequency from when you turned them off, so it may be necessary to tune around to find them. A spectrum display is a big help here, and should be set for the widest practical frequency width.

The ARRL website lists some common home appliances that can be sources of RF noise. Being on this list doesn't mean that it will cause RFI, but that some appliances of its type have been found to generate RFI. The list includes Electric Blankets, Heating Pads, Clean Air Machines (table top and furnace type) Aquarium Heaters, Furnaces and Furnace Control Circuits, Refrigerators, Amplified Antennas, Door Bell Transformers, Light Dimmers, Ceiling Light Fixtures, Low Energy Compact (screw-in) Florescent Lights, Touch Control Lamps, and Photocells.

**Peeling the Onion:** All of us here in the real world hear noise from many sources, the strongest ones obscuring the weaker ones. Finding and killing RFI is a many-layered process, like peeling an onion – when we kill those strong ones, we can go after the weaker ones.

**Tools For Identifying Sources:** W6GJB reports that an MFJ-805 current probe was helpful in finding RF noise currents on cables. The unit is quite simple, and can easily be home-brewed for a lot less than the \$100 cost of the MFJ. It's simply a coupling coil wound on a clamp-on ferrite core that is temporarily clamped around the cable we want to check for noise; the coil feeds a diode detector, filter capacitor, DC meter, and series pot to set meter sensitivity. These applications notes describe several good ways to do it. [http://www.w8ji.com/building\\_a\\_current\\_meter.htm](http://www.w8ji.com/building_a_current_meter.htm)  
<http://www.ifwtech.co.uk/g3sek/clamp-on/clamp-on.htm>  
<http://www.interferencetechnology.com/the-hf-current-probe-theory-and-application/>

Portable radios that use a ferrite loopstick antenna make a much more sensitive probe for common mode current at frequencies where the radio uses the loopstick (below 10 MHz for the TH-F6A). Simply hold the loopstick perpendicular to the cable you're probing. At higher frequencies, use the rubber duck as an RF probe. A menu selection also allows the SMA connector to be used at any frequency, and the Tecsun PL660 has an antenna input in the form of a 1/8-in TRS jack.

### How Noise is Coupled Into and Out of Equipment and Systems

**Noise Is Conducted From Equipment Onto Cables** when cable shields are not bonded to a shielding enclosure at the point of entry, or when unshielded cables are not properly bypassed to the shielding enclosure. The failure to properly terminate shields was first addressed by Neil Muncy, ex-W3WJE (SK) in a landmark paper first published in the Journal of the Audio Engineering Society in June 1995. He called it "**The Pin One Problem**" because Pin 1 of the XL connectors used for microphones and other audio interconnections is the shield contact. Pin One Problems are a primary cause of RFI, providing a path both into and out of equipment for hum, buzz, and RF noise.

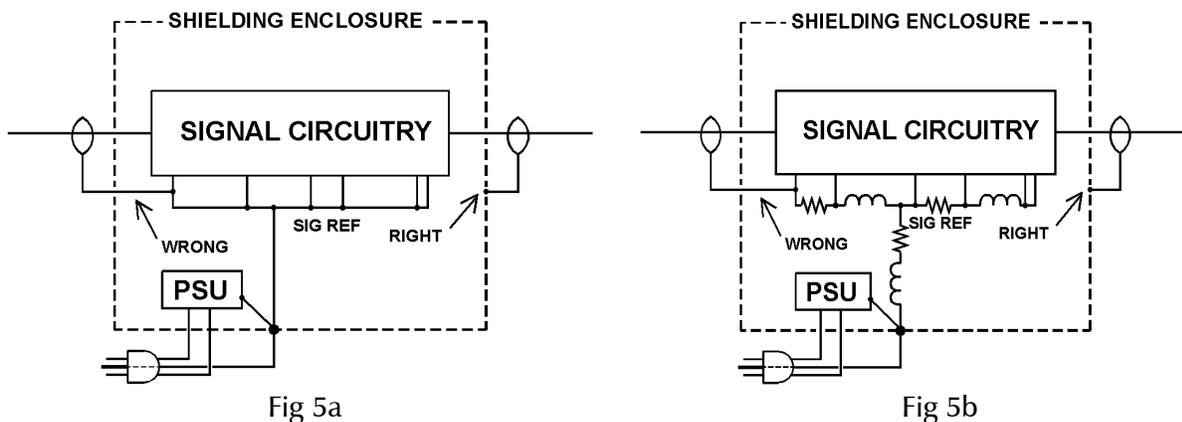


Fig 5a illustrates "The Pin One Problem" and Fig 5b shows how it couples shield current into active circuitry. Shield current on the output cable flows to the shielding enclosure and from there to the power system equipment ground conductor (the "green wire"). All noise current stays outside the equipment, so it can't couple to the equipment.

Shield current on the input cable flows to a return trace on the circuit board on a path at the whim of the PC board layout artist, and eventually gets to the same power system ground conductor. As it traverses the return trace(s), IZ voltage drops are established across the R and L of the path, and the potential difference is injected at the input of one or more active stages where it is amplified (and, if it's RF, is detected by diode action at a stage input).

Pin One Problems on both input and output cables cause hum, buzz, and RFI, and signal flow logic cannot be used to find them, because layout of the signal return path, which often has nothing to do with the signal path, determines where noise is injected. **And because the cable shield connects to some random point inside the unit, any noise present at that point will couple onto the cable shield and be radiated by the shield. This is a major cause of RFI from equipment.**

Because of the way printed circuit boards are manufactured and mounted in equipment, it is rarely practical to correct Pin One Problems without major surgery that is likely to turn into a major engineering project to fix circuit instability. And, of course, we don't want to do anything that affects a product warranty, nor do we want to open up our neighbor's TV set, computer, or WiFi router. The far better solution is to kill the current on the cable shield, both 1) by choking it with a suitable ferrite choke, and 2) by shunting the current away from it by bonding all equipment chassis together and to the ground system for the shack and the building.

**Magnetic Field Coupling** of noise is proportional to the strength of the current, the area of the loop in which the current flows, and the loop area of the receiving circuit. Loop area is minimized when forward and return conductors are run closely in parallel, and is increased when conductors are spread out – for example, at battery terminals of a solar power system, or to circulate through multiple batteries wired in series. Magnetic field coupling is a primary coupling mechanism in DC power circuits, like solar power systems and variable speed motor control systems.

**Noise Can Be Radiated By the Equipment Itself** if circuit layout is poor and the unit is unshielded or poorly shielded. One common design error is wiring that forms an antenna or a current loop with a large loop area. A common design error producing this result is breaking the “ground” layer on a multi-layer printed circuit board. At radio frequencies, the return current for a trace on a circuit board with a “ground” layer will be confined to a narrow area directly underneath the trace; the trace and the “ground” layer form a transmission line, so there can be no radiation from that circuit trace. All of that breaks down if the “ground” layer is broken under the trace – it's like any other coax with an open shield! When this happens, the return current takes whatever unintended path is available, and the result is both an antenna and strong magnetic coupling.

The only known fixes for such equipment are: 1) rewire/rebuild the equipment to eliminate the current loops; 2) completely shield it, bypassing all cables that penetrate the shield to the shielding enclosure; 3) give it “the bucket treatment.” [The Bucket Treatment: Find a bucket large enough to hold the defective device, fill it with water, put the defective equipment in twice, and take it out once.]

**Twisted Pair** is far superior to parallel conductor cable (zip cord) in minimizing noise coupling. All noise sensitive circuits and all circuits carrying noise currents, especially those carrying large currents, should utilize twisted pair. It's easy to make your own twisted pair. All the DC wiring for my small solar system uses #10-2 THHN that I twist by cutting equal lengths of black and white stranded #10, clamping one end of both conductors in a bench vise and twisting them with a portable drill motor. Over the years, I've solved many RFI issues with home entertainment systems by replacing the zip cord used for loudspeaker wiring with twisted pair.

**Suppressing Electronic Noise:** Now that we've identified a source and know how noise is coupled, it's time to suppress it. There are two good ways to skin this particular cat. Often it's easiest to replace the noisy component with one that isn't noisy. I've scoured flea markets and second hand stores to put together a large box of old wall warts for equipment that I no longer own. They're bigger and heavier than a modern switch-mode wall wart, because they contain a linear power supply – that is, a simple transformer followed by a rectifier and a filter capacitor. They're a bit less efficient, but they're dead quiet!

**Replace The SMPS:** There are (at least) two good ways to utilize these old linear supplies. First, we must determine their open circuit voltage and their voltage under load. Next, we must determine the voltage and current needed by the electronics that it must power. When we find a linear supply that matches the equipment in question, we simply cut the cables for the two supplies and splice the linear supply to the cable that feeds the equipment. For greater flexibility, I install a Red/Black Power Pole connector pair s on cables from the linear power supply and the equipment.

**Float-Charge a Lead Acid Battery:** A second technique I've used extensively is to obtain a fairly small ordinary sealed lead-acid (SLA) battery of the voltage used by the equipment and use a linear wall wart to float-charge it. I use Power Pole connectors universally for DC power in my home and shack. It's easy to make a few parallel adapters to connect the charger and several pieces of equipment to a single battery. In my home, one such setup powers my cable modem and wi-fi router.

[El Nino rains caused us to lose power for 18 hours during ARRL DX SSB; the internet router and WiFi system was still running when power was restored!] Another float-charged battery powers four 12V accessories in my home entertainment system (a cable box, a Roku box, a DVD player, an Apple TV, and a “trucker’s” FM modulator that feed an internet “radio” around my home and yard). I have three more small float-charged batteries running Samsung computer monitors that run on 12-14VDC, and another with a 6V battery running an “internet radio” for which the specified voltage is 7.5V.

When implementing this strategy, carefully select a supply that provides enough current to run the equipment without over-charging the battery. SLA batteries will generally accept a charge less than their 10 hour discharge current without degradation. These linear supplies may or may not include a capacitor input filter, and their DC voltage will vary under load. Always measure battery voltage and charging current after the battery is charged and the equipment is running. A silicon diode in series with the charger will reduce charging voltage by 0.6 – 0.7 V; one or more diodes can prevent overcharging. Over-charging a battery can ruin it, so make sure that charging current is no greater than battery’s rated 10-hour discharge current. I find the inline Watts Up digital meter (Fig 6) to be a convenient way to monitor voltage and current. One caution though – it measures current in the negative lead, so can give wrong answers if there’s a return path through interconnected equipment. A better choice is the more expensive HamSource EZMeter, which meters in the positive lead.

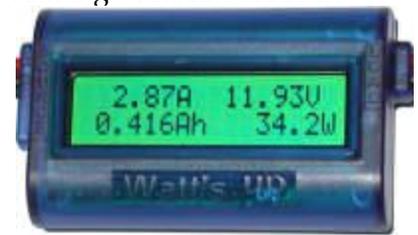


Fig 6 – Digital Meter

Likewise, in the shack, all the rigs and their 12V accessories run from a big 12V battery that is float charged by a 20A supply and, during the summer months, four solar panels. Equipment powered from this system includes three more Samsung monitors, antenna switching, etc. Each one of these setups functions as a simple UPS. When power fails, my internet, WiFi, the internet “radio,” FM modulator, and those computer monitors keep right on going. And since those computers are laptops, so do they. Good bye switch-mode power supply noise!

**Kill the Current With Ferrite Common Mode Chokes** Sometimes it isn’t practical to get rid of the noisy equipment – it may be expensive, something rather specialized, your XYL’s favorite lamp, or something in your neighbor’s home –so we must suppress the noise. The most useful technique is to apply a suitable ferrite common mode to the cable(s) that carry the noise current and radiate or receive the noise current. Our weapons of choice for the HF bands are clamp-on cores and toroids made with Fair-Rite Products #31 and #43 material. #31 is superior below 5 MHz, #43 is a bit superior above 14 MHz. I’ve always recommended #31 because it’s a far more universally usable part, so we can save money by buying only #31 in larger quantity.

===== Sidebar =====

### How Ferrite Chokes Work

Common mode chokes work by adding a large value of **resistive** impedance in series with the common mode circuit. Most hams think of a common mode choke as an inductor. That is VERY wrong. Common mode chokes work using the **resistance** of the **parallel resonant circuit** formed by the inductance of the winding, the stray capacitance of the winding, and the resistance coupled from the lossy core.

The self-resonance of a conductor passing once through most ferrite cores used for suppression is in the range of 150 MHz, and this is where a core simply clamped around a cable will be effective. To obtain good suppression in the range of 1-50 MHz, we must wind multiple turns through the ferrite core to lower the resonant frequency. Inductance, of course, is the inductance of a single pass through the core multiplied by N squared, where N is the number of times the wire passes through the core. Because that resistance is inductively coupled, it is also multiplied by N squared. C is mostly the capacitance between turns, so it increases approximately proportional with the number of turns, and is a bit greater with large diameter cables. It can also be increased by squeezing the turns very close together (outside the core),

or reduced by forcing them apart. Because these chokes are intentionally very lossy, their circuit Q is quite low (around 0.5) so precise tuning is not required.

At low frequencies, the fundamental equivalent circuit is simply that series R and L (because the value of C is too small to matter at low frequency), but as frequency increases and we approach resonance, C is in parallel, and for an octave or two both sides of resonance (an octave is a 2:1 frequency range), the circuit simplifies to parallel R, L, and C, where L is the inductance at low frequencies, C is the capacitance well above resonance, and R is the parallel equivalent resistance transformed from the series value.

The reason we want high resistance in our choke is that in the common mode circuit, which is really an antenna, the rest of the circuit can look inductive or capacitive depending on its length. A simple example is a dipole fed with coax, with the shield grounded at the transmitter. The common mode circuit consists of the dipole plus the coax – the coax looks like a grounded vertical long wire with top-loading wires. If, for example, that vertical wire is between  $\lambda/4$  and  $3\lambda/4$  wavelength, it will look inductive; if it is shorter than  $\lambda/4$  or between  $3\lambda/4$  and  $5\lambda/4$  it will look capacitive. These relationships will repeat as the electrical length increases. If we had a choke with little resistance, it would still have parallel L and C values, which would form a series resonance with the L or C of that wire at some frequencies. When that happens, the common mode current will INCREASE, and be limited only by the resistance of the choke. But if the choke has enough resistance, that R will limit the current. Another example of a common mode circuit is a cable running between two pieces of equipment.

In the real world, we rarely model these circuits, because there are far too many variables that are subject to change from one installation to another. Instead, we take a "brute force" approach, making the resistive component of the choking Z as high as possible for the widest practical frequency range in which we need suppression. And if we need suppression over a wider range than one choke can cover, we add a second choke tuned to the rest of the operating range.

Ferrite materials that have "good" suppression characteristics are lossy in the frequency range where suppression is desired, although nearly all have low loss at much lower frequencies. Fair-Rite materials #31, #43, #44, #61, and a few others are optimized for suppression, and in that operating range, the circuit Q of their parallel resonance is on the order of 0.5. This allows a choke with a well placed resonance to cover a bit more than an octave. #61 material is an example of a material that is lossy at UHF, and thus useful for suppression above about 400 MHz, but has low enough loss below 20 MHz that it can be used as a core for high power transformers for the HF bands.

Most of these materials are NiZn compounds, and possess only the circuit resonance described above. #31 material is unique – because it is a very special MnZn compound, it exhibits both the circuit resonance at higher frequencies and a dimensional resonance at lower frequencies. When the circuit resonance is below about 6 MHz, the combination of the two resonances gives its impedance curve a very broad "double-humped" response, much like a stagger-tuned IF, providing nearly an extra octave of effective suppression. Its equivalent circuit is two parallel resonant circuits in series. Note that all MnZn materials exhibit dimensional resonance, but only in Fair-Rite's #31 is it carefully controlled to provide the broad-band suppression described here.

===== End of Sidebar =====

Fair-Rite Part Number	Shape	i.d. inch	o.d. inch	Length inch
0431164181	Clamp-on	0.5	1.55	1.22
0431173551	Clamp-on	0.74	1.15	1.65
0431177081	Clamp-on	1.0	1.7	2.2
2631803802	Toroid	1.4	2.4	0.5

Table 1 – Useful Ferrite Cores

**How Many Turns?** For 40-10M, wind 5 turns through the clamps in Table 1; for 80-160 wind 7 turns, and for 6M use two turns, with several chokes in series. For chokes on toroids, use the data for small diameter wire in Appendix One of <http://k9yc.com/RFI-Ham.pdf> or the guidelines for small diameter coax in the Choke Cookbook in the same document. When counting turns, it's the number of times the cable passes through the ferrite core (one more than visible in the loop).



Fig 7a – Randomly Wound Choke

**Winding Guidelines** It is important to wind turns through the ferrite core in sequence. Out-of-sequence turns cancel, raising the resonant frequency and reducing the choking impedance. Because the turns in Fig 7a are randomly wound, that choke will not be as effective as the chokes in Fig 7b and Fig 7c. These chokes might be used on the cables of the home entertainment system or a computer monitor. The 5-turn choke (Fig 7b) is most effective on the higher HF bands, and the 6-turn choke (Fig 7c) is even better (larger core, another suppression on the lower HF bands at the expense of the higher ones. Adding two more turns through the larger core moves the resonance down for improved Always use a cable-tie around “snap-on” cores so that the two pieces fit tightly together – if the contact is poor, the choke won't work at all!



Fig 7b – 3/4" i.d.



Fig 7c – 1-in i.d.

**What Cables Should be Choked:** Start by choking every cable connected to each noise source that you discover. If you can't kill the noise from that source, turn it off and move on to the next source. Continue choking all the noise sources until all are either successfully choked or turned off. Now you know what products are not fixable, and can think about replacing them with something better.

**Buying Ferrite Cores:** Never buy ferrite cores from vendors that advertise in ham magazines – they're selling at insanely high markups, and often the wrong parts for what we need. Instead, put together a quantity order for members of local ham clubs and buy from one of several good industrial vendors. You'll pay about 25-30% of what those ham vendors charge, and you'll get the right part. My current favorite vendor is Dexter Magnetics (near Chicago), others speak well of Lode-stone-Pacific, and these two vendors are usually most competitive, but sometimes Allied and Newark are as well. I've been happy with Kreger Components, but their prices have not been competitive in recent years. All of these vendors will bill a credit card and charge it when they ship. This usually provides enough time to collect most of the money from your buyers. Don't go by catalog prices -- once you have some idea about quantity, call them for quotes (and price breaks) for the quantities you think you might buy. Add to those quotes the cost of shipping and sales tax for your state.

Always buy full boxes – ferrites are brittle and break easily, but there will be virtually no breakage if they come packed by the factory – ask about box quantities. These vendors can ship a single order to 2-3 locations if that makes it easier for you to deliver, but don't ask them to split boxes. Never re-ship ferrite cores – they must be very well packed to prevent breakage, they're heavy, and they're expensive to re-ship. Insist at all buyers in the group pick up their order at a club meeting, or passed along from another member who does the pickup for them. Our first ferrite buy was split between clubs around Los Angeles and SMC members in three cities.

Table 1 [see Part One of this article] lists part numbers for cores I find most useful for suppression at HF and on 160M. All are #31 material. Lately I've been buying the 0.74-in i.d. clamps because I find them most universally useful. They're large enough for the medium-size cables I need to choke, like cables to video monitors and many power cables. The 0.5-in i.d. clamps are large

enough for smaller cables, and are cheaper. The 1-in i.d. cores are pretty expensive (about \$10) but are equivalent to three 2.4-in o.d. toroids; I save them for the largest cables.

**Commercial Power Line Filters** are generally effective only if installed inside equipment and bonded to the shielding enclosure. They are generally not effective when mounted outside equipment. The reason is simple – RF noise gets onto the Equipment Ground conductor (the “Green Wire” when it is not properly terminated to the chassis where it enters the noisy product (just like “The Pin One Problem,” and the “Green Wire” does not go through the filter! This fact is further confused by the way in which “differential mode” and “common mode” is defined for power systems – differential mode voltage is that between Line (hot) and Neutral, and common mode is that between Neutral and the Equipment Ground (the Green wire). This is very different from how we as communications engineers define common mode, and the way we define it is what causes antenna action. Filters are specified as having common mode suppression, but they do nothing about suppressing common mode current! The same sort of common mode choke we would use on coax will be equally effective on power wiring.

**Evaluating Equipment For Noise:** When someone tells you that XYZ equipment produces no noise on the ham bands because he can’t hear any noise in his radio, should you believe that the equipment is clean? **NO!** The equipment may be noisy but he doesn’t hear it because it is being covered by other noise from the neighborhood. Figs 8 and 9 compare the daytime 80M spectra at K6GFJ in a San Jose residential neighborhood and K9YC 30 miles to the south in the Santa Cruz Mountains. The difference in the noise floor is 10 dB. And it’s certainly not dead quiet in the mountains, either – everything on the displays from both QTHs is noise from either switching power supplies or other electronic sources.

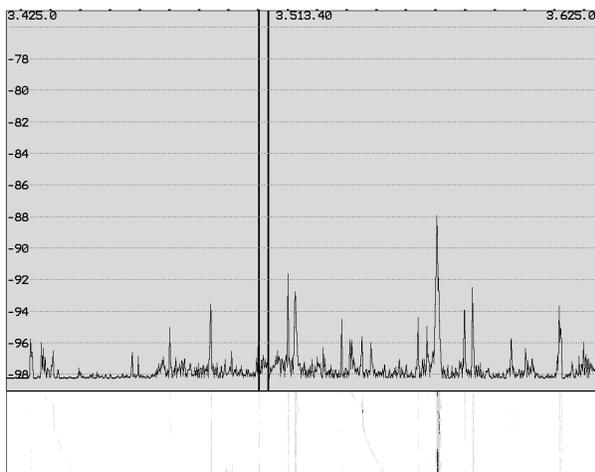


Fig 8 – 80M at K6GFJ – Noise floor -98 dBm

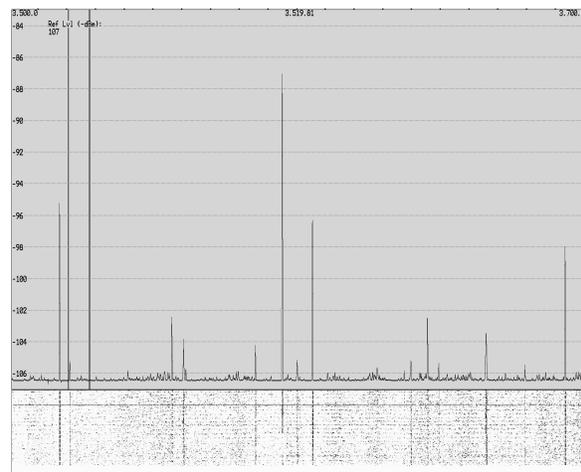


Fig 9 – 80M at K9YC – Noise floor -108 dBm

**Proximity to Antennas Is What Matters:** Noise radiates from sources on wires that are connected to noise sources, and enters our receivers via our *antennas*. My SteppIR that’s up 120 ft and is 200 ft from the shack doesn’t hear much noise from the shack, but the 160M Tee vertical only 25 ft from the operating position does. When someone tells you that a particular model of internet router or video monitor sits next to his power amp and there’s no RFI, ask him how far it is from his *antennas*, not from his radio.

**An Exception – Magnetically Coupled Noise:** When a noise source produces strong magnetic fields, it can couple noise into equipment in close physical proximity to the victim (see Part One). Noise is coupled via the magnetic field to any circuit loop nearby, and to any victim equipment that has a similar circuit layout problem. Magnetic coupling dominates over electric field and electromagnetic field coupling in the near field of the source. The solutions to magnetically coupled noise are 1) to reduce the area of the loop carrying the noise current, 2) reduce the area of the loop in the victim circuit, and 3) separate the source and victim by as much distance as possible. In general, this means using twisted pair or coax for all signal wiring and running it in close proximity

to bonding conductors between the equipment it interconnects (because the bonding and the signal wiring forms a magnetic loop).

Several years ago, ON4WW put up an excellent web page with more than twenty case histories documenting the successful pursuit of a variety of RF noise. It's well worth a read. <http://www.on4ww.be/emi-rfi.html>

### Issues With Specific Product Types

**Low Voltage Lighting:** This generic type consists of any lamps and bulbs that run on DC voltage, including those in most architectural lighting fixtures, many track lights, and LED lighting. Incandescent types CAN run on an ordinary transformer, but transformers large enough to power them don't fit in the electrical enclosures within walls or ceilings, so switch-mode power supplies are almost universally used. All that I have seen are unbranded, unlabeled, noisy pigs. They are sold by electrical supply houses, where they are called "electronic transformers."

Track lighting now comes in several forms. The track itself can carry "line voltage" (120VAC) or low voltage (12 or 24VDC). Track that carries low voltage is fed by a 24V supply, which could be a transformer (quiet), but is usually an SMPS (noisy). Fixtures for "line voltage" track can utilize 120VAC incandescent bulbs, in which case they will be as quiet as any other incandescent bulb. Sadly, over the last decade or so, manufacturers have gradually shifted to low voltage fixtures that use a switch-mode power supply built into the base of each lamp holder so that it can be connected to a line voltage track. Any noise produced by those supplies will be radiated by the wiring within the track and the wiring feeding the track. The only practical place to choke these noise sources is where external wiring feeds the track, but the parallel wires within the track are efficient radiators.

**LED Lighting:** LEDs are very efficient, requiring relatively low values of DC voltage and current for a lot of light, but there still must be a DC power supply somewhere. For screw-in 120V LED replacements, the DC power supply is built into the base of the bulb. Any noise produced will be radiated by the AC line. To suppress that noise, the line should be choked as close as practical to the bulb. A noisy outboard supply, if there is one, should be choked at its input and output terminals. Several years ago, ARRL tested a broad selection of LED screw-in bulb replacements and found them relatively clean. The bad news is that things change when products become a commodity – local hams report that off-brand LED bulbs from the local big box store were quite noisy, while Phillips bulbs, among those ARRL reviewed, were relatively quiet. My advice – try a few in fixtures that are close to antennas and see if you hear them. And if they're noisy, return them for full credit, and make sure you tell the vendor that "they made noise in your radio."

Faced with noisy low voltage lighting, I'd still look for LED replacements -- their much lower current requirements could make it practical to replace the existing noisy supply with a quiet linear supply that's small enough to fit in the available space. I'm lighting my shack with five LED strips that I bought at Pacificon from Wired Electronics. The combined load is about 1.25A from the 12V system that runs my radios. The shift to LED lighting has already produced some LED lamps that are direct replacements for existing fixtures, and that trend is certain to continue.

**Grow Lights** can be a very powerful source of RF noise that can be heard a half mile away! These 600 – 1,000 W sodium or metal halide lamps run from ballasts that include switching power supplies in the range of 50-75 kHz. None are certified to Part 15 or 18 of FCC Rules. Wiring between the ballast and the lamp is usually fairly long and can form a large loop, so is rather efficient at ham frequencies both as an antenna and as a magnetic loop.

Tom Thompson, W0IVJ, and Larry Banks, W0QE, have researched these lamps extensively, and Tom has developed an effective filter which is designed to be applied between the ballast and the lamp. Tom found that a filter on the power line side of the ballast was less effective. A commercial version of Tom's filter, built by W7LOZ, is available at

<http://growershouse.com/revolution-ballast-emi-filter-reduce-rf-emi>

A report on Tom and Larry's work, including a schematic of the filter, is at <http://tomthompson.com/radio/GrowLight/GrowLightBallastFilter.html> Also, there's recent good news from W0IVJ – some ballast manufacturers are starting to place the ballast on the lamp hood, which reduces the

loop area, reducing the both the magnetic field and the size of the antenna that can radiate the noise. In addition, Tom thinks that the Galaxy Grow Amp model 90220 may pass Part 18, but the extent to which this kills emissions will likely depend strongly on the loop area of the connection to the lamp.

Tom's filter suppresses only noise radiated by wiring on the lamp side of the ballast. That may be sufficient for many installations, especially where noise is at 5 MHz and above. In more severe cases, or where RFI is present below 5 MHz, a common mode choke on the power line side of the ballast may also be required. Follow the recommendations in the Choke Cookbook in <http://k9yc.com/RFI-Ham.pdf> for small diameter coax (RG8X) for RFI in the frequency range where you hear the noise, running the line cord through the choke. W0QE shows a very different filter design on his website. [http://www.w0qe.com/RF\\_Interference/grow\\_light\\_electronic\\_ballasts.html](http://www.w0qe.com/RF_Interference/grow_light_electronic_ballasts.html)

**Switch Mode Power Supplies:** If you must use an SMPS, plan on adding suppression to it. Start with common mode chokes on both the 120VAC and low voltage DC lines for the frequency range(s) where you hear noise. Capacitors across the DC output terminals and the AC input terminals can also help. Select capacitors for low ESR (equivalent series resistance) at the frequency of interest and on the AC line side, use only type X1, X2, Y1 and Y2 capacitors, which are specifically rated for AC line use and designed to withstand the 3-6 kV spikes that can occur on power wiring. Choose this capacitor carefully – if it fails, it could catch on fire!

SMPS units tend to be noisiest at lower frequencies, especially on 160M. Fig 10 shows a choke wound with 18 turns of #16-2 "zip cord" on a 2.4-in o.d. #31 Fair-Rite toroid. It is intended to provide strong attenuation of SMPS noise on the 80 and 160M bands. It can safely be inserted in circuits carrying up to about 12A of AC or DC current without danger of overheating. This short length of #16 (about 4 ft) does not increase resistance enough to affect charging current.



Fig 10 – A 80/160M Choke



Fig 11 – 12VDC to 120VAC 1A Inverter with Required RF Filtering

**DC-AC Inverters:** The Samlex PST-series of "pure sine wave" DC-AC inverters carry an FCC Part 15 Class B rating for RF noise, and are relatively quiet, but may not be quiet enough for any given installation, depending on proximity to antennas for the bands you want to operate. (Part 15 Class A is a much looser specification for industrial applications, and allows 20 dB higher noise levels than

Class B, which is for residential use.) The Pure Sine Wave inverter in Fig 10 carries FCC Part 15 Class B certification, but had to extensively choked to kill radiated noise. The smallest clamp-ons are for 2M; these and the three smaller multi-turn chokes (0.75-in i.d.) were sufficient when powering the logging computer for our 7QP mobile operation. As an experiment, the two larger (1-in i.d.) chokes (above the unit in Fig 11) were added in an attempt to suppress RFI to the 160M vertical 25 ft from my shack, and were not nearly enough, so I wound the choke shown in Fig 10, which helped.

**Uninterruptable Power Supplies (UPS)** come in two basic types: *On-line* types are always regenerating power, while *Standby* units monitor the AC line and regenerate power only when AC power fails. Both types include batteries to provide the power when power fails, a DC power supply to keep those batteries charged, and a DC-AC inverter that operates when the unit is producing AC power. If the DC power supply is an SMPS, it will likely produce RF noise while charging the battery. All of the comments about DC-AC Inverters and SMPS apply equally to UPS units.

**Variable Speed Motor Controllers** are often used in furnaces and HVAC systems. These controllers are notoriously noisy for at least three reasons. First, they consist of an SMPS, the DC output of which is then pulsed at variable width and speed to control the speed of a motor. Both of those pulses are rich in harmonics, and they are radiated by wiring both internal and external to the unit. This radiation tends to be quite strong because the designers have failed to consider the impact of circuit layout on noise. Thus, loop area tends to be quite large, which increases antenna action and greatly increases the magnetic field produced by the noise current. Variable speed controllers are also widely used for motors in elevators and geothermal systems where both motor currents and loop areas are even greater.

Solutions include rewiring circuits with large loop area carrying motor current with twisted pair. Some product manufacturers sell optional filters to prevent noise from being conducted onto the power line, but that does not prevent that interior wiring from radiating.

N9TF reports electronic noise in the range of 20-23 MHz spaced about 17 kHz. The source is a Samsung washing machine, and lasts as long as the wash cycle. Peaks on 15M are 18- 20 dB above his noise level. Gene provided these videos of this noise, that are currently at the links below. [k9yc.com/SamsungWasher1.mp4](http://k9yc.com/SamsungWasher1.mp4) and [k9yc.com/SamsungWasher2.mp4](http://k9yc.com/SamsungWasher2.mp4)

**Plasma TVs** produce strong RFI that extends up to at least the 12M band, and it is just about impossible to suppress. The best solution is to replace it with an LCD model. The noise is produced by the current inside the display structure that it takes to light up each pixel turning on and off, and the magnetic and electromagnetic fields produced. In other words, the noise is not radiated by external wiring, but is radiated by the display itself. There's no way to suppress it short of major re-design of the display to either shield it or confine the fields by means of microstrip or stripline construction. Chokes on external wiring will have no effect at all on noise radiated by the currents within the display. Thankfully, plasma TVs are no longer manufactured, but existing units will continue to be used for years.

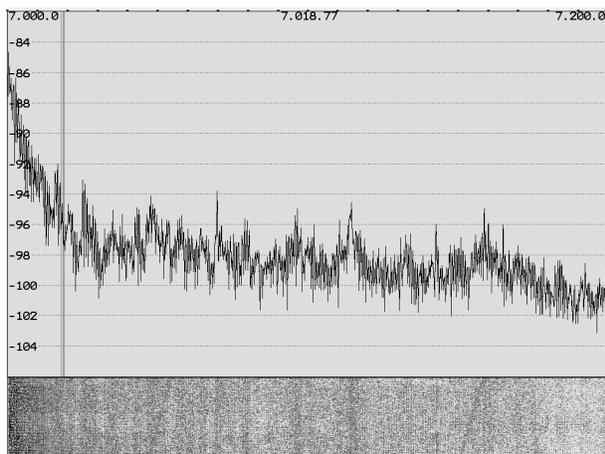


Fig 12: Plasma TV, 7 – 7.2 MHz

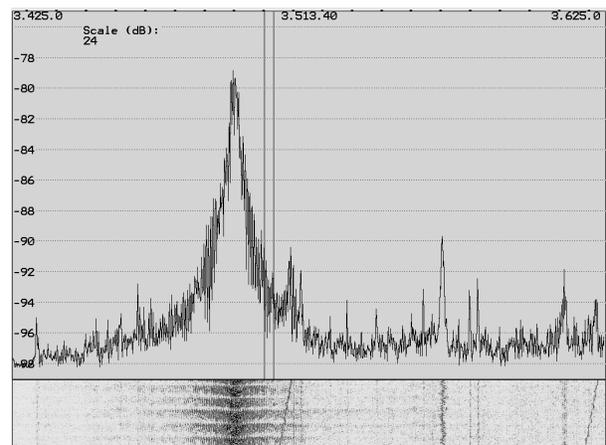


Fig 13: Plasma TV, 3.425 – 3.625 MHz

**Typical Plasma TV Noise Spectra** are shown in Figs 12 and 13 (K6GFJ) and Fig 14 (K7PI). K6GFJ's data is from his K3/P3/SVGA fed by a low dipole, and looking at his own NEC PlasmaSync 50MP2 TV. The bottom of each of the amplitude displays is the noise level at Ross's QTH in a San Jose residential neighborhood. Fig 8, from K7PI's SDR, shows a wider spectrum for his neighbor's plasma TV. Note that the spectra will be strongly dependent on which of the dozen or so common DTV video standard signals are being viewed at the time. There's more spectral data for plasma TV RFI at [k9yc.com/publish.htm](http://k9yc.com/publish.htm)

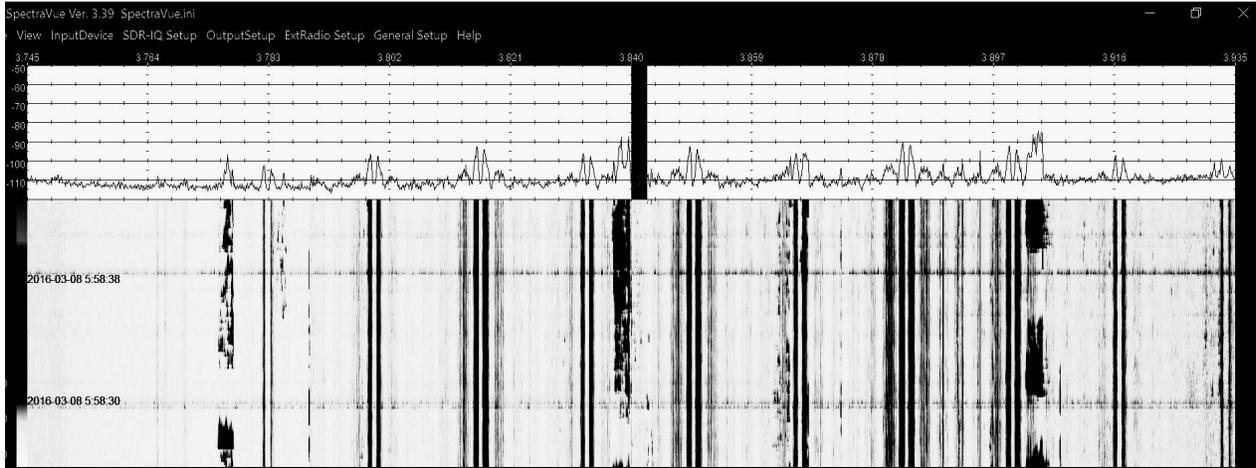


Fig 14 – A Neighbor's Plasma TV at K7PI – 3,754 kHz – 3,935 kHz, 10dB/div

There can, of course, be other noise radiated by the unit – a switching power supply and other circuitry separate from the display itself. These components would most likely be radiated by cables connected to the unit and can be suppressed with chokes.

**Wired Ethernet RFI** on the HF bands (the carriers around 14,030, 21,052, and the low end of 10M and 6M) can be suppressed by choking every cable connected to the Ethernet switch. Both ends of the cable are potential noise sources; cables that are shorter than about  $\lambda/10$  at the frequency of interference can be choked in the middle with a single choke. Longer cables should be choked at both ends. Don't forget to choke the power supply cable. As noted earlier, you'll hear both your own carriers and those of your neighbors; to identify yours, kill power to the Ethernet switch and note which carrier disappears. Gauge your success on the reduction in strength of your carrier in each group; to kill the carriers from your neighbors you'll have to choke their cables. When setting up a network, always try to avoid the use of wired Ethernet; instead use WiFi if it will work reliably for your installation.

**VDSL and Cable Modem UpLink Leakage** in the range of 3.7 – 5 MHz shown in Fig 2 of Part One may be radiated by wires connected to modem itself or from the telephone or CATV company's wiring between homes. WA7JHZ and W0IVJ have documented this problem with spectrum measurements of the common mode signal on coax carrying CenturyLink and Comcast systems in Idaho and Colorado. It should be possible to suppress leakage from the modem with a 6-7 turn choke on each cable wound around a 1-inch long #31 clamp-on, but so far, cable and telcos have stonewalled. This would be a good issue for ARRL to address.

**Computers:** Some are RF-quiet, but many radiate RF from internal wiring, and from wiring for power and connected accessories. Some are quiet at HF but noisy at VHF. If a computer is noisy, choke all cables connected to it.

Some **Computer Video Monitors** are noisy, some are not. Choke both video and power cables on the noisy ones. Some cannot be suppressed – W4UAT gave me a Samsung with "touch" controls that he couldn't use because it went nuts when he keyed a radio feeding a nearby antenna. Nothing I tried could kill the noise it made in my receiver, nor prevent it from turning flips when I transmitted. Not all Samsung monitors are noisy – I've replaced all the monitors in my home and shack with 24-in Samsung models sold with outboard 14VDC switching power supplies, which I run from float-charged 12V batteries (see Part One.)

**USB Powered Equipment** like USB sound cards and computer extension speakers often includes a switch-mode power supply to convert the 5V USB voltage to that that the powered unit can more effectively use. Add equipment like this to the list of potential noise sources, and treat them like any other – choke the cable(s), and if that doesn't kill the noise, replace the noisy product. W6GJB reports that noise from a pair of USB-powered speakers radiated not only on their own USB cable, but also on every cable connected to the computer!

**Noisy Doorbell Transformers**, often buried in the walls, can be nasty sources of impulse noise. WX5L reports that “the older type doorbell transformer has a safety feature built in. A thermistor monitors the heat in the windings. If it detects overheating it, it opens a relay to disconnect power so it doesn't combust. But even with a normal situation this relay can become pitted and chatter away causing RFI.” The defective transformer should be replaced with one that is UL or ETL listed. *[UL and ETL are safety inspection laboratories certifying the electrical safety of components connected to the power line. They do not test the quality or effectiveness of a product.]* If the transformer is inaccessible but its AC wiring is accessible, it should be disconnected and an alternate doorbell system installed. Most building codes require that all wiring associated with the mains system (120 and/or 240VAC) must be accessible.

**Solar Power Systems** can be very strong noise sources as a result of poor design, poor installation, or both. The best charge current regulators are DC-DC converters, and most are noisy. DC – AC inverters that provide 120VAC are also often noise sources. Both charge and discharge circuits carry large pulsed currents with strong harmonics; those harmonics will radiate if the current flows through large area magnetic loops. A large system with all wiring in steel conduit has the best chance of being quiet, ***provided that the conduit is continuous and bonded to all equipment enclosures at both ends.*** Solar power systems should always be wired with twisted pair. Genesun, a relatively new company makes a line of MPPT (the most efficient type) solar charger regulators for small systems that is quiet enough for nearly all installations (although I needed the choke of Fig 10 in mine to completely kill noise in a 160M vertical next to the panels). <https://genasun.com/products-store/mppt-solar-charge-controllers/> Most solar systems include DC to AC inverters, which as noted earlier are often noisy.

There has been a trend in recent years to solar panels with self-contained regulators and inverters; properly built and installed, these can greatly reduce the loop area and thus the noise. Because the power leaves the panel as 120VAC (or even 240V), wiring from the panel is usually in conduit. And because the output of the panel is at the higher line voltage, the current is much less than if it were at battery voltage. RF trash produced is directly related to current, so all of these factors can combine to result in less radiated noise if the units are well designed.

**April 2016 QST** includes a feature article on modern home solar power systems with respect to RF noise. There many good things about the article – a good discussion of overall system architectures in general and for this system in particular, recognition of the interconnection of solar panels and batteries as a magnetic loop, recommendation for the use of twisted pair for that loop with return circulating through the loop to minimize radiation and the loop area, recommendations that wiring be installed in steel conduit, and recommendations for the use of ferrite common mode chokes for suppression of noise currents. It also shows how much work it is to fix a bad system!

I have two problems with this article. First, the author, rather than searching out and buying a system that produces minimal RFI (or insisting that the vendor and/or manufacturer fix his RFI problems), instead buys a “bad” system and goes to considerable trouble and expense to fix it himself! How many hams will buy this product because QST has showed them how to fix it? And what do you do if the noisy system belongs to your neighbor? Second, there are a few significant technical errors, mostly related to specific recommendations for the common mode chokes.

**Active Noise Cancellers** When we've done our best and still have noise, an active Noise Canceller can make a big dent in a ***single*** source, but it won't help with more than one source at a time. Noise Cancellers work by combining signals from our receive antenna with the signal from a “sense” antenna located near the source of the noise. The adjustable phasing network within the unit must then be carefully tweaked so that the two signals are equal in level and 180 degrees out of phase. This adjustment is frequency sensitive, so it must be readjusted each time we QSY. It

must also be readjusted for every noise source. The MFJ 1026 and the DX Engineering NCC-1 are generally well regarded. Be careful when using any unit in line with the transceiver output – the carrier detector in my Timewave ANC-4 generated so much IMD that K6XX rang my phone within an hour of when I tried to use it that way.

**Fluorescent Lighting** can be noisy or quiet, mostly depending on the type of ballast used. Many screw-in replacements for incandescent bulbs tend to be quiet, but can become nasty noise generators when they get old and begin to fail. Traditional tube-type fluorescents use either older-style magnetic (linear) ballasts, which tend to be relatively quiet (until they fail) or more efficient electronic ballasts, which have the same noise issues as SMPS. Electronic ballasts are rated for industrial use (FCC Part 15 Class A, noisy) or residential use (FCC Part 15 Class B, about 20 dB quieter). With help from his local power company, W9RE traced severe interference on 15M to fluorescent lighting in a home 1,500 ft away.

Replacing an industrial-rated ballast with a residential unit can reduce the noise significantly. Noise is radiated by the tubes and wiring within the fixture, and on the ac power line. A common mode choke on the ac line can suppress the power line radiation, but shielding is generally required to kill radiation from the fixture. The shielding must be a continuous screen or mesh, and must be bonded to the fixture, and some scraping of paint may be required.

K6LL and W7WW report success with this line of LED replacements for fluorescent tubes that need no ballast – the AC line must be re-wired direct to the LEDs with no ballast. This work should be done by a qualified electrician.

[earthled.com/collections/t8-t12-led-fluorescent-replacement-tube-lights-that-bypass-ballast-rewire](http://earthled.com/collections/t8-t12-led-fluorescent-replacement-tube-lights-that-bypass-ballast-rewire)  
Direct plug-in replacements for fluorescent tubes are now being sold by “big box” stores. They are designed to work with existing ballasts. The jury is still out on how quiet they are; I’ve seen some positive reports, but see “Evaluating Equipment For Noise” at the beginning of Part Two.

#### Another Source of Power Line Impulse Noise

AC0C traced strong power line noise at his QTH to MOV lightning arrestors on power lines, some of them two miles away. They are connected between Line and Ground, and create a path between the power line and the tower’s downlead to it’s local ground rod. MOVs degrade over time as they absorb the joules from each spike, and as they age, conduct on increasingly lower voltages until the are conducting on the peaks of the AC cycle. At this stage, every cycle is creating noise that is radiated by both the power lines and the downlead. The only solution is for the power company to remove and replace them. Jeff provided these excellent photos.

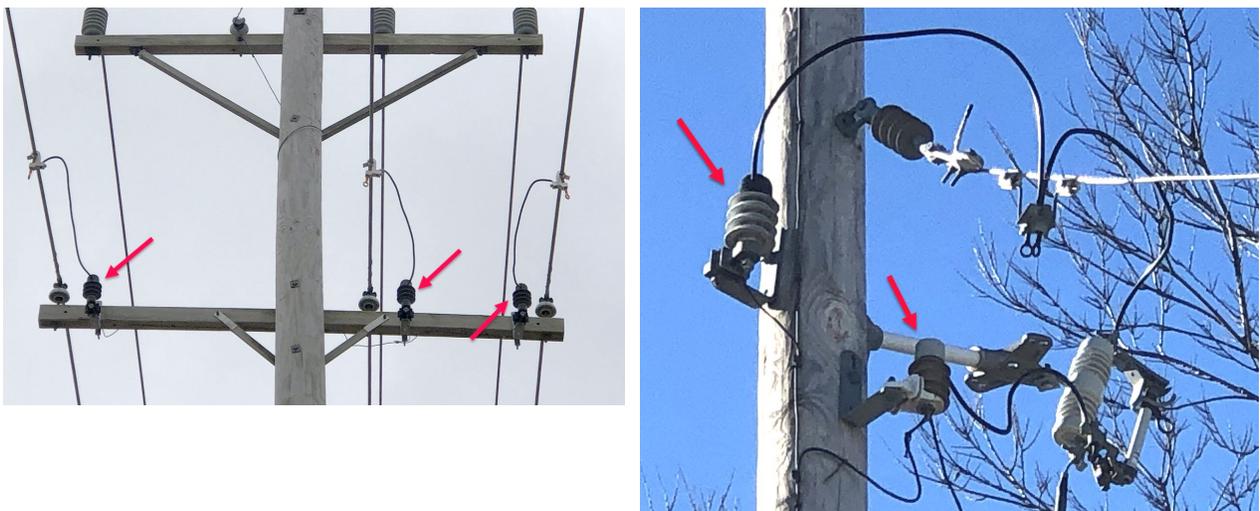


Fig 15 – MOVs on Power Lines (Photos by AC0C)

## Action Summary For Killing RF Noise

**Study a Spectrum Analyzer Plot** to determine whether it is impulse noise or electronically generated, and if electronically generated, its characteristics. Review Part One.

**Is it impulse noise** – broadband, no variation within a band, strongest at low frequencies, gets weaker with increasing frequency, covers a fairly wide area? If yes, it's probably something arcing within the power company's distribution system, or occasionally a neon sign. Try to get a bearing with a directional antenna, then listen with a mobile rig tuned for AM around 160 MHz, then when it gets loud, zero in on it by listening with an AM detector at UHF. When you hear it loud at UHF, get out of the car with a talkie tuned to that range. Then communicate what you've learned to the power company.

**Is it electronically generated noise** – harmonically related carriers that repeat every 10-100 kHz, stronger in some bands than in others? If the carriers are wobbly in frequency, are surrounded by humps of noise, and drift a bit over time, the source is likely an SMPS. If the carrier(s) are relatively stable in frequency, the source is likely within digital equipment. Begin your search by listening with your rig running from a battery as you kill power to everything in your home, then finding and suppressing each noise you hear as you turn on one circuit breaker at a time.

Remember that most of us hear many noise sources, both impulse noise and electronic noise, and from many sources. The key to success is to identify and tackle them one at a time.

**Kill electronically generated noise** by replacing noisy products with clean ones, or by applying common mode chokes to all wiring connected to each source, one at a time. If there are multiple sources on a circuit, turn all off but one and suppress it, then turn that source off and move on to the next. When you find a source you cannot suppress, turn it off and work on the others.

**When a new noise appears, think like Sherlock Holmes.** What new product have you (or your neighbor) bought? Is there a pattern to when you hear it? Can you connect that pattern to patterns of use of something that could be a noise source? Is it the same every day (perhaps tied to a circuit that senses daylight) or appliances that are used at certain times?

### Using A Spectrum Analyzer To Chase Noise (and DX)

We can maximize the visibility of signals (and man-made noise) with several important settings.

- 1) Set the analyzer for maximum averaging, and with repetition rate in the range of 100-250 msec. Averaging is a powerful signal analysis tool because it causes all random noise to average out to near zero, but signals are reinforced because they are coherent (i.e. not random).
- 2) Adjust reference level so that the bottom of the display is the level of the averaged "white" noise
- 3) Set the scale of the display so that the strongest signals fills most (but not all) of the height of the spectrum display.
- 4) Set the width (frequency span) wide enough to see any variation in noise with frequency. For example, many electronic noise sources repeat every 10-30 kHz.

When we've done this correctly, the bottom of the amplitude display will be the average of the white noise, and the waterfall will go to black anywhere there are no signals or electronic noise sources. Figs 1, 4, 8, 9, 12, and 13 illustrate this technique with an Elecraft P3, which allows frequency span to be adjusted over the range of 2 - 200 kHz. An important benefit of setting the analyzer this way is that it causes very weak signals to show up in the waterfall as faint traces against a black background. This can be very helpful when looking for DX, especially on a nearly dead band.

Figs 2 and 14 are the displays of SDRs (software defined radios) whose displays can be set for a much wider frequency span. The wider span allows us to see more patterns in the noise. Be cautious about reading too much into the relative strength of noise (and signals) over a frequency span greater than the bandwidth of the antenna you're using, or wider than the bandwidth of any band-pass filters that may be between the antenna and the SDR.

Note also that I have post-processed all of these analyzer “screen grabs” by converting them to grey scale and turning them negative to make them print better in hard copy. I didn’t do that in earlier versions of this applications note, and the detail didn’t show up nearly as well.

NK7Z has developed some excellent methods for using a spectrum analyzer to chase RFI, and has many spectrum plots of known noise source types on his website. <https://www.nk7z.net/>

===== **End of Sidebar**=====